

pupation; those collected a fortnight later were in various stages of growth and included newly hatched individuals, which were on the undersides of the leaves, while the more mature ones hid in the upper layer of the soil. Under laboratory conditions the emergence of the adults from the collected pupae lasted till the end of August, but in nature the moths were on the wing as late as September and the first week of October. At the end of October the larvae burrowed into the soil to a depth of about six inches or deeper and constructed a hibernaculum. The author thinks it probable that hibernation occurs also in the adult stage, but gives no evidence for the statement.

This proves that in Poland the insect frequently passes the winter as a larva and the same is probably true of other parts of Northern Europe including the British Isles, though it is doubtful whether many survive in this country. It is unlikely that many of our September and October moths live until the spring. Though they often swarm near the coast in the autumn, records of their capture in the spring are few, and the collectors, to whom I have spoken, say either that they have never seen one or that they have only seen one on rare occasions. A male, very slightly worn, which I took at Braemar on June 27th, 1931, may have hibernated, but this is the only one I have seen so early in the year.

I think most of our moths die in the autumn after laying their eggs or without laying them at all, as those kept by Mr. Hawkins did, and that the usual stage during the winter is the larval one. I have little doubt that an occurrence such as that described by the Rev. J. Hellins is quite exceptional. It is strange that so little is known in England about this common moth, and that our books are still quoting an observation made in 1863.

*Voroniecka-Siemaszko. *Polski Pismo.* 1928. vii. 193-201.

* [*E.M.M.* IV. 135. Nov. 1867.—T.B.-F.]

Effects of Temperature on the Development of *Zerynthia rumina*.

By ORAZIO QUERCI.

I. RECORDS CONCERNING THE DEVELOPMENT IN PORTUGAL.

(1) In the month of January, 1933, the temperature at Lisbon varied from min. 32° to max. 59° ; on 3rd February it increased reaching 69° on the 5th, and then we took a male of *Zerynthia* (*Thais*) *rumina*, L.; but after the heat decreased (no lower than 60°) and until 13th March we took but a few males and a female which, from their poor condition, looked to have emerged several days before.

(2) The emergence of the *rumina* occurred from 14th March (max. 64°) to 7th April (max. 79°); however, the specimens, looking as if born on the day of their capture, were taken only when it was at least 62° .

(3) After 7th April the *rumina*, which we saw near Lisbon, were worn and the last female of that year was seen by us on 27th April.

(4) The single and worn female, which we took in February, was put into a breeding-cage with some plants of the *Aristolochia* upon which the larvae feed. For eight days the weather was fine but rather cold (max. 55°) and that *rumina* ♀ did not flutter until 24th

February (max. 56°) when she laid some eggs and died. Those eggs stayed a fortnight without hatching (max. 60°) and on 8th March (max. 63°) some eggs hatched and others dried up.

(5) The young larvae remained dormant, owing to the moderate heat for twelve days (max. 58° to 62°), and little by little died. We understood that in such a climatic condition the larvae of the *rumina* cannot live, and we expected more suitable weather to get other eggs. That was a mistake because at the beginning of April the heat increased up to 79° ; many pupae were certainly formed in the country, but not in our broods, there being no big larvae.

(6) Many eggs were laid in our cages on 23rd March (59°) and they stayed for eight days at the temperature of about max. 64° , hatching on 31st March (max. 66°).

(7) The larvae of this batch grew rapidly from 3rd to 8th April (max. 79° , min. 51°), but after that date they became laggard (max. 73°) and on 19th to 21st April (max. 63°) they ceased to feed and some died.

(8) On 24th April the temperature rose to 75° and the larvae, which were still alive, started eating again, being more or less active for a week (max. 66° to 71°). A few of them were almost full grown when from 1st to 6th May the maximum was no more than 63° , and most larvae rotted. Only three larvae remained on the stems without feeding on the leaves which we set close by them. On 9th May (74°) one of these larvae turned active, ate a bit of leaf, hung up and formed the pupa on 12th May, 1933 (85°). That pupa was taken with us when we went to Tangier, Morocco, where the adult emerged on 10th May, 1934.

(9) The other two larvae of that batch turned active on 11th May, 1933 (75°), hung up on the 14th (80°) and changed with great difficulty on the 17th (89°). Those pupae turned black and died a few days after.

(10) A female of *rumina* laid at least 70 eggs on 22nd April (67°), they hatched on the 29th after the temperature had been for a week max. 75° , min. 52° .

(11) On 1st May the temperature dropped (max. 63° for six days) and all the larvae remained very small and dried up.

(12) In April of 1933 we took near Lisbon many larvae of *rumina* of different sizes. The smallest ones died after the cold weather (max. 63°) on 19th to 21st April, others rotted during the long wave of cold (max. 63°) at the beginning of May. A few of the biggest larvae resisted but only three of them pupated when the heat increased (max. 89°) in mid-May. The remaining larvae either collapsed, or formed imperfect chrysalids which died.

II. RECORDS CONCERNING THE DEVELOPMENT IN NORTHERN MOROCCO.

(13) At Tangier the temperature rose sometimes to 63° or 69° both in February and early March of 1934, and we took a few males and a female of *Zerynthia rumina*; afterwards, until the beginning of May, we caught specimens of both sexes. During that gradual emergence it was almost max. 63° .

(14) In May all the *rumina* on the wing were worn, and some of them were almost devoid of scales. We believe that there are specimens which remain hidden for several days.

(15) From February to April of 1934 we put into the cages some females which laid many eggs, hatching, in accordance with the climate, almost in the same time as at Lisbon (records 4, 6, 10).

(16) Both in March and April the larvae died quickly, being unable to feed, for lack of activity, as the temperature was rarely above 63°.

(17) On 20th April (65°) a female of *rumina* laid about 50 eggs; afterwards she was killed by the radiant heat (118°). By the end of April it was sometimes 66° or 68°, and the eggs hatched on 2nd May, but a few dried up.

(18) Besides those home-born larvae we took in the country, in May of 1934, many caterpillars of *rumina* of the most different sizes, which we reared apart. At Tangier the kind of *Aristolochia* is different from that of Lisbon, and the larvae are reddish while in Portugal they are grey.

(19) From 3rd to 24th May the climate at Tangier was a little milder than in early spring, being almost always max. 68°, min. 53°, and rarely rising to 72° or 74°. The growing larvae, which are inactive only when the temperature is below 64° (records 5, 7, 11, 12, 16), were not injured, but they grew slowly and only a few matured. As soon as the larvae matured they left the plants, cleared their intestine and stopped upon the nets of the cages, spreading a little silk around them, but after some time, as the temperature did not increase, they moved and tried to hang elsewhere. This useless work continued for a few days and those big larvae gradually became weaker, as besides the loss of silk and energy they rarely fed, and at last they became quite dormant.

(20) On 16th May (74°) we set the cages with these larvae in the sunshine (98°) and one of the larvae hung up and formed the pupa after two days (74°).

(21) On 18th May the weather was unsettled and the larvae in the sun (100°) fed actively. In the afternoon a larva hung up and pupated on 21st May (74°).

(22) From 19th to 24th May (max. 68° to 74°) the larvae stayed sometimes in the sun but none hung up and some of the dormant ones collapsed. On 25th May the thermometer marked 76° and the day following it rose up to 77°, however, the weather was sultry and many mature larvae rotted. On 27th May the heat decreased (70°) and the larvae were less active.

(23) At 7 a.m. of 28th May (74° in the shade, 97° in the sun) we made another exposure of the larvae in the light, and most of them fed actively, but two hours later the heat increased (77° in the shade, 118° in the sun) and the caterpillars became so excited that we set a shelter against the heat, and many larvae hung up. The following day was cloudy and sultry (about 70° for the whole day), and not only some big larvae rotted, but also a few of the suspended ones collapsed. We considered that the intense radiant heat had injured the whole brood, but the larvae which died were only those which had been longest in the mature stage, and would probably have never recovered. None of the other larvae were injured.

(24) Until now more than 70 of the larvae hatched at the beginning of May were dead and only two had pupated, but after 29th May the climate settled with the optimum range of pupation for the *rumina* (77° to 82° for some hours every day) and all the larvae, which had

hung up on 28th May, and had not died on the 29th, formed the pupae on the 30th, while the others grew, matured, hung up and pupated rapidly, both in the sun and in the shade. At the beginning of June 298 pupae of *rumina* were formed in our cages, and on 8th June all our larvae had pupated save one. Cleaning the cages we found 83 larvae, which had either dried or rotted, and 18 pupae looking sick, which afterwards died.

(25) Of the 50 larvae hatched at home on 2nd May (record 17) only four were still living on 3rd June (79°), and they hung up on the 6th (80°), but one pupa was formed on the 9th (79°), and the other larvae pupated incompletely and collapsed.

(26) The single larva of *rumina*, which did not pupate on 8th June (record 24), was reared by us with care and sometimes it ate a little bit, but by the end of June we could find no more *Aristolochia* and that larva died.

III. TEMPERATURE EXPERIMENTS.

(27) Rearing some different species of Lepidoptera we had remarked that the pupae kept in winter in our warmed rooms produced adults after those, of the same batches, which we kept out of the window. We thought that an exposure in the cold is needful to the regular development of the pupae, and having many chrysalides of *rumina* we tried to get some out of season specimens from the effect of the cold in summer. On 15th June, 1934, we put into a refrigerator at 30° to 40° a lot of 38 pupae and at the beginning of September (78°) we took out 10 of them expecting that they should have not emerged as the temperature was still above that at which the *rumina* appear in the country, and none emerged. On 2nd October the heat decreased and we took out the other pupae which had been for three months and a half in a cold room. Those chrysalides delayed more than we expected in producing adults, and a male emerged on 17th November, a female on the 20th, and 12 other *rumina* climbed along the nets of our cages from 23rd November to 3rd December of 1934. On those days it was about max. 64°, min. 54°, that is almost the same as in March, when the *rumina* were more frequent in the country. A few of those adults were sent, by air mail, to the Museums of Natural History of Tring, London and Madrid, and to Mr. Hy. J. Turner at Cheam, and those butterflies arrived still living both to England and Spain. Of the 28 pupae, which had stayed long in cooling, 14 did not emerge at Tangier; however, one produced the adult in February of 1935 in the cabin of the steamer by which we came to Greece.

IV. GENERAL CONCLUSIONS.

(The figures in a parenthesis correspond to the records.)

EGGS.—Until the maximum temperature was below 61° the eggs of *Zerynthia rumina* did not hatch, and as soon as it was 63° some eggs hatched in a fortnight, but others dried (4). The hatching of the eggs required a shorter time if the daily quantity of heat increased (6, 15, 17), and when the maximum varied from 67° to 75° after the eggs were laid they hatched after a week and none dried up (10).

YOUNG LARVAE.—The young larvae were unable to feed, for lack of activity, and in a few days they starved upon verdant plants if after

their hatching the temperature remained below 64° for some time (5, 11, 16).

GROWING LARVAE.—The larvae, which met with a suitable climate after their hatching and were able to grow a little, resisted a subsequent period of cold weather, and some of them matured (7, 8, 9, 12, 19). The most resistant larvae were those almost full grown, but not yet mature. The radiant heat does not injure the growing larvae if it acts for a moderate time (23), and also in the country most larvae of *rumina* do not hide when the sun is shining. As soon as the temperature settled above max. 76° the larvae grew and matured rapidly even in the shade (24).

MATURE LARVAE.—The insufficiency of heat (less than 77°) prevented the mature larvae from suspending at once, and they being almost unable to feed became dormant (8, 19). In our cages only a few mature larvae resisted for long the unsuitable climate and hung up when the weather turned hot (8, 7, 12, 20, 21, 25), but most collapsed (12, 22, 23, 24). The larvae which matured when the temperature was above 86° and the vapour pressure was not high, (22, 23) hung up at once even in the shade (24).

SUSPENDED LARVAE.—Only two of about 800 larvae of *rumina*, which we have reared, formed the pupae at a temperature a little lower than that at which all the other larvae pupated in our cages (20, 21), and when that happened the vapour pressure was very low. The radiant heat hastened the end of the exhausted suspended larvae, but a moderate exposure did not injure the others (23). Above 76° the suspended larvae pupated in a short time, if they had recently matured (24); on the other hand, also at the optimum temperature, they delayed pupation for some days if they had remained long in the mature stage (8, 9, 12, 20, 21, 23, 24, 25). The most weakened larvae did not recover, even if the heat increased above the point of pupation, and they either collapsed without commencing to pupate (12, 23), or formed imperfect pupae which soon died (9, 12, 25).

PUPAE.—The pupae of the *rumina* go over the winter wherever that species occurs. We have obtained the premature emergence of some pupae after the effect of the artificial cooling (27). The lowest temperature at which a few pupae produced adults was 62° (2, 13).

IMAGINES.—A female of *rumina*, which was already old when we took her, lived nine days in a cage (4), another female laid more than 70 eggs in about two hours (10), however, the experiments of this kind made at home cannot give support to a guess of what happens in the open country. One female laid some eggs when the maximum temperature was 56° only (4).

CONTROL OF THE FERTILITY.—Both at Lisbon and Tangier the larvae of the *rumina* were injured neither by lack of food (24, 26), nor by parasites. None of the larvae taken in the country were affected with mites. The chrysalides long resisted the cooling (27). Only a few eggs were unable to hatch (4, 17). The most active factor controlling the abundance of the *rumina* was the mild climate, which allowed the adults to emerge and lay eggs, which hatched at low temperature (4, 6), but prevented many larvae from developing.
